§17. Status of Negative-Ion-Based NBI Systems of LHD

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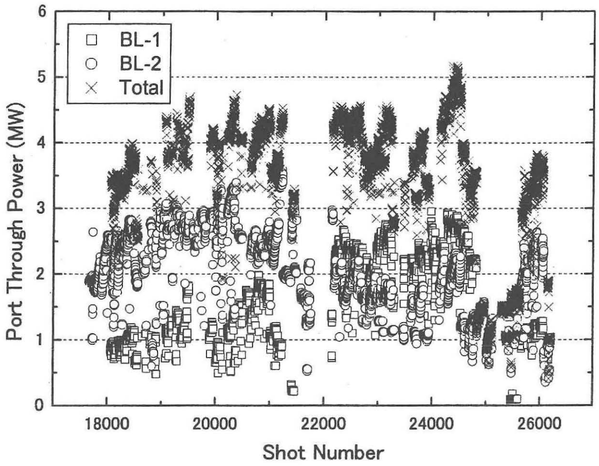
The neutral beam injection heating system of LHD is based on the negative-ion-beam technology because of its required high beam energy. After the start of neutral injection heating experiment in 1998 at the second experimental campaign of LHD, we have been making our efforts on conditioning of ion sources to increase the injection power. During the conditioning process, we have experienced several problems on the beamlines, most of which were related to the water leak of the cooling channels in the ion sources or in the beam line components.

In the FY 2000, the fourth experimental campaign, we succeeded to increase the beam energy up to 170keV while the designed value is 180 keV. The port through power was also increased to 5.2MW as beam energy. However, the negative ion current still stayed at a half of the designed value. The main reasons of this limitation are the spatial non uniformity of beam (or plasma?) in the longer direction of the rectangular ion source, and the amount of electrons included in the accelerated beam.

Figure 1 shows the results of port through power shot by shot during the fourth campaign. It is noted that from this campaign the beam injection was available in every three minutes. Previously, it was nine or twelve minutes due to the required time for evacuating the outgas after the NB injection shot. Therefore total injection shots during the campaign (about four months) was over 5000. This repetition time is convenient for the operation of negative ion source because the temperature of plasma grid must be kept as high as 200℃, and this is done by the heat from plasma discharges in the plasma source. As can be seen from the figure, the maximum total port through power was 5.2 MW, but each injector achieved more; 3MW for BL-1 and 3.5MW for BL-2. Unfortunately the best performance of each injector could not be realized at the same time. Therefore, the improvement of reliability is another problem.

Figure 2 shows the history of injected beam energy. Usually, the ion source was operated at the highest beam energy that was available unless particular conditions are required from the experimental condition. BL-1 started at rather low energy level because of the trouble just before the experimental campaign, and gradually increased its energy during the campaign. On the other hand, BL-2 started in good condition and achieved its highest energy in the middle of the campaign, but the small water leak occurred in the ion sources and lowered its performance.

Figure 3 shows the relation between the port through power and the pulse width. We were careful about extending pulse length for protecting the girds from the excess heat load. Typical pulse length was 2-3 s for the moderate power level because a flat top of plasma parameters were usually achieved after 2s. As a result, pulse length decreases as the power increases because the heat load on the grids of ion source increases.



.Fig.1 Injected beam power during the third campaign

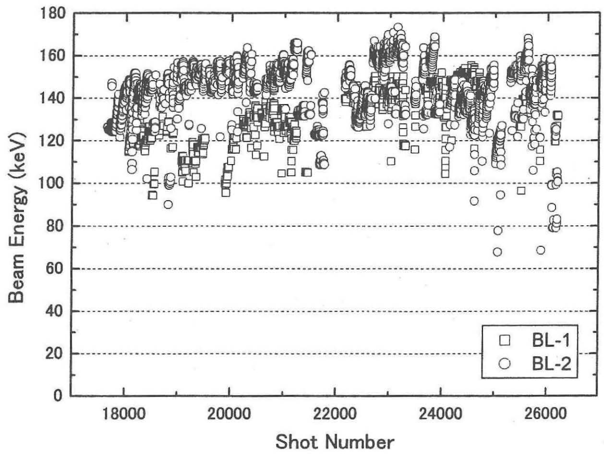


Fig.2 Beam energy and ion current vs. shot number

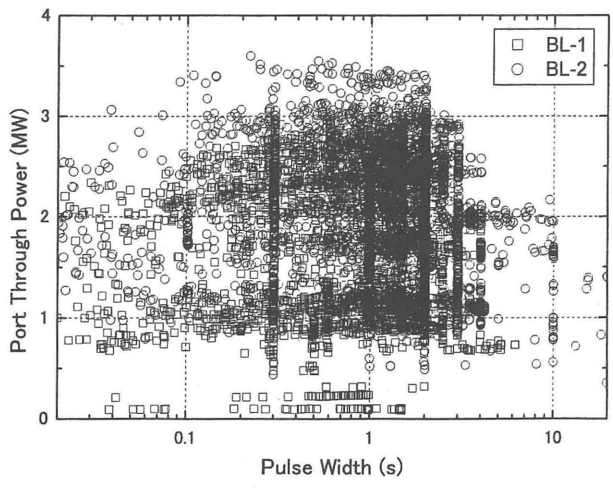


Fig.3 Beam power vs. pulse length.